International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN (P): 2249-6890; ISSN (E): 2249-8001
Vol. 8, Issue 6, Dec 2018, 69-74

TRANS STELLAR
• Journal Publications • Research Consultancy

APPLICATION OF AUTONOMOUS ROBOTS FOR HEALTH MONITORING OF STRUCTURES: A REVIEW

SHALINI R NAIR[1], SHYAM R NAIR[2] & JESSY ROOBY[3]

[1]*Assistant Professor, Department of Civil Engineering, Hindustan Institute of Technology and Science, Chennai, Tamil Nadu, India*

[2]*Assistant Professor, Centre for Automation and Robotics, Hindustan Institute of Technology and Science, Chennai, Tamil Nadu, India*

[3]*Professor, Department of Civil Engineering, Hindustan Institute of Technology and Science, Chennai, Tamil Nadu, India*

ABSTRACT

This paper highlights the status with regard to structural health monitoring and robotic application on structures. This review begins with application of autonomous robot for damage detection and inspection, which goes on to discuss robots that are developed for mobile platform and various sensors employed to sense the defects. This paper includes the application of artificial intelligence that helps in automated data collection and data analysis techniques to improve several aspects of the construction engineering, safety management, risk analysis and prediction. It includes vision based robotic senses for structural health monitoring, vision based structural crack detection, visual based structural displacement monitoring and wireless structural health monitoring. The focus of this review is identifying the structural health monitoring research efforts that include damage detection, risk analysis and structural capacity evaluation. The paper concludes that the criterial gaps includes a lack of validated structural health monitoring that use artificial intelligence to examine structural integrity and predict the remaining life of the structure.

KEYWORDS: *Robotics, Automation, Health Monitoring & Structures*

Received: Aug 01, 2018; **Accepted:** Aug 21, 2018; **Published:** Oct 15, 2018; **Paper Id.:** IJMPERDDEC20187

A REVIEW

INTRODUCTION

Civil structures are fundamental to the society. Due to various adverse operational and environmental conditions, civil structures are under continuous deterioration during its life span. More than a quarter of the bridges in United States were categorized as structurally deficient or functionally obsolete [1]. The American Society of Civil Engineers estimated that between one third and one fourth of infrastructures are structurally deficient and requires a huge amount of investment to safeguard them[2]. Thus, it can be inferred that Health Monitoring Technology has to become efficient for existing and new infrastructures. The consequences of neglecting health monitoring of structures range from minor to catastrophic. From literatures it is evident that bridges, sewages and pipelines require an inspection schedule [2]. With implementation of systematic approach, maintaining a healthy infrastructure is challenge. Structural deficiencies increase with increase in age of a structure. Not only has life span of structure, but also urban growth and development played a vital role in creating the need for the maintenance of structures. Natural disasters like hurricanes, earthquakes, or accidents and their after effects demands inspection and maintenance of structures in that locality. Factors that interrupt routine

inspections are manpower and funding. Mobile robotic systems can overcome the above-mentioned factors.

Robotics is one of the fastest growing engineering fields today. Robots are primarily designed to replace man labor from dangerous and inaccessible environment. Inspection and maintenance of various structures are expensive and dangerous; hence assigning these tasks to robots appears to be one of the feasible solutions [3]. If mobile robotic systems are implemented for surveillance tasks, structural health monitoring integrated with mobile robots will be the best solution to overcome factors such as dangerous tasks and inaccessible problems in structural health monitoring. There is increase in production of various remote-control inspection units for structural health monitoring, which can be considered as evidence of the effectiveness of Robotic systems [2]. Commercialization of Mobile robotic systems in the field of Structural Health Monitoring depicts the fact that, widespread implementation of robotic systems may occur in the near future. The current technologies implemented in this field e.g., remote control, tethered systems, have their limitations for health monitoring. Hence, there is potential for deployment of practical autonomous systems to overcome these limitations.

From various literatures it is evident that long-term continuous surveillance of a structure provided by an autonomous inspection system could be far more safe and cost-effective than employing human resources [2]. Wide range and enhanced inspection capabilities provided by mobile robots improve the accuracy of structural assessments. From the observations of researches till date, it can be suggested that development of complex autonomous systems incorporating improvements in mobility and processing capabilities are necessary before robotic systems can be deployed without human guidance. With new emerging trends in robotic technology, the implementation of fully autonomous systems in Structural Health Monitoring may soon be realized.

APPLICATION OF ROBOTICS FOR STRUCTURAL HEALTH MONITORING

At preliminary stages, Robotic application primarily focused on the inspection of structures rather than Health Monitoring. The robots with unique locomotion systems have enough mobility in structures for the purpose of inspection. These systems have to be equipped with sensors such as vision cameras, optical-fibers, lasers, etc. to monitor [4]. Robots existing at present for Inspection of structures are:

- Wheeled robots
- Wall-climbing / Crawling robots
- Snake-like robots
- Modular robots
- Aerial vehicles.
- Underwater vehicles

Robots specialized for Structural Health Monitoring applications are expected to increase in the near future[V].

SENSORS USED IN STRUTURAL HEALTH MONITORING ROBOTS

The sensors used in Robots for Structural Health Monitoring are cameras, Optical Scanners and Fiber Optics. Robots are not only used as sensor carriers, in some research they are also used for wirelessly delivering electrical power to Structural Health Monitoring sensor. Inductive power transmission with Radio Frequency (RF) signals (Huston et al., 2001) or optical delivery using power lasers can be used for this purpose (Park et al., 2010, Bang et al., 2011).

AREAS OF APPLICATION OF ROBOTS

Areas in structural systems, where, man cannot access due to lack of space or other reasons, inspection may be carried out with help of special robots. For example, robots for sewerage inspection (Kirchner and Hertzberg, 1997, Adria et al., 2004), pipe cleaning and inspection (Li et al., 2009), and tube inspection (Kostin et al., 1999) have been developed.

Inspection and Damage Detection

Inspection and damage detection are vital part, which must be a continuous process throughout lifespan of structures. Damage detection is possible either by comparing two states of an infrastructure using a sensor, or by detecting the changes in the structure parameters, so as to detect the damages. In order to monitor safety of structures, various sensors and sensory systems have been developed. In recent years, robotic prototypes have been developed to make them in real time applications for Structural Health Monitoring.

Bridges and Bridge Cables

For steel bridges, the inspection is carried out using magnet-based locomotion (Mazumdar and Asada, 2010, Zhu, 2010, Romero, 2010). For inspection of cables, wheel-based (Xu et al., 2008) or reconfigurable robots (Yuan et al., 2010) have been developed.

Pipelines and Sewerage Systems

Concept Structural Health Monitoring is applicable in the fields of inspection of pipelines and sewerage systems to improve the condition of the system and increase its lifespan. It is difficult to equip the entire pipeline with sensors; another method is put forward by researchers to monitor the condition of the inner surface with the help of a surveillance robot. This concept was first introduced in nuclear power plants with the help of cable drawn wheeled carts having a camera recorder attached. With development of sophisticated sensors and actuators, fully autonomous robots based on various motion generation systems and integrated with multiple sensors are being developed today. Among these, some of the robots can travel long distance inside the pipelines to record the surface condition and locate damages.

Sewage collection systems are vital part of any country's infrastructure. Due to deterioration of pipes, inflows such as groundwater and rainwater seep into the pipe systems. Improper assessment of these conditions causes the country to invest a huge amount on repair works of sewers and pipe systems. Proper investigation and assessment at the right time significantly reduces sudden failure of pipe and sewage systems. The effective inspection system for sewer pipes is gradually gaining importance, and is considered a mandatory procedure. An autonomous robot, if developed for condition monitoring of such system will save a huge amount for maintenance of such systems, which will save overall maintenance costs in a country..

Autonomous Robots for Inspection of Structures

Autonomous robot is an intelligent mechanical system that functions autonomously. If applied for inspection, the required action will be carried throughout the process in a repetitive way. An inspection robot must consist of 1) A Conveyor: Which carries various inspection instruments and is controlled by an inspector in order to collect data. 2) Inspection Instrument: This inspects the structure. The inspection instrument may include adequate sensors, actuators and logic unit. Time required for data collection and analysis will be reduced, since sensing and computing are synchronous in such a system. As per observations from various literatures, the most challenging aspect in developing autonomous robot

for inspection is Motion Planning. The existing methods adopted for Motion Planning are: i) The Transversal Path Planning, ii) The Longitudinal Path Planning iii) Random Walk Method and Obstacle Avoidance Method. J. R. Chang, *et.. al;*. In 2007 proposed an integrated method, which includes all the above-mentioned methods for Robotic Pavement Inspection Path.

Crack Detection

For any concrete structure to be structurally sound, it must be periodically monitored for crack development. Conventionally engineers adopted manual identification and detection which is a tedious job, and Chances of accumulation of errors are high in this method. Identification of cracks at early stage helps to prevent further development and damage of the system. With help of autonomous mobile robots, researchers have developed computer vision based damage detection and analysis of cracks. In this method, high quality images of concrete surfaces are captured and analyzed to build an automated crack classification system.

Overall Structural Health Monitoring

In recent years, wireless monitoring has emerged as a developing technology, which greatly impacts the field of structural monitoring and infrastructure assessment. For the development of wireless structural health monitoring system, researchers used wireless sensing units to build structural health monitoring systems that interrogate structural data for signs of damage. Once the hardware and the software designs of wireless sensing units are completed, the Alamosa Canyon Bridge in New Mexico was utilized to validate the accuracy and reliability of the developed wireless system. In order to improve the ability of low-cost wireless sensing units, the wireless sensing unit paradigm is extended to include the capability to command actuators and active sensors. From review of literatures, it was clear that all the preliminary studies of structural health monitoring and their applications were implemented on bridge structures. There is a future scope on implementation of these systems to tall structures.

APPLICATION OF ARTIFICIAL INTELLIGENCE

In many situations of civil engineering, where mathematical models fail to simulate the complex behavior of real life situation, Artificial Intelligence has been successfully applied. Areas like prediction, risk analysis, decision-making, resources optimization, classification and selection [VI]. In the field of waste management, database, or construction Artificial Intelligence has shown its potency toper form better than the conventional methods. Embedding sensors within structures to monitor stress and damage can reduce maintenance costs and increase the lifespan. This is already being used in over forty bridges worldwide. Similar application can be extended to tall structures to reduce maintenance cost and improve its lifespan. From literatures, it is clear that there is a lack of validated structural health monitoring that use artificial intelligence to examine structural integrity and predict the remaining life of the structure

CONCLUSIONS

This paper highlights the application of autonomous robotics in various fields of civil engineering such as autonomous robot for damage detection and inspection, application of artificial intelligence, vision based robotic senses for structural health monitoring, and vision based structural crack detection, wireless structural health monitoring and application of artificial intelligence. The paper concludes that the criterial gaps includes a lack of validated structural health monitoring that use artificial intelligence to examine structural integrity and predict the remaining life of the structure.

From close observations, it may also be concluded that all these technologies are implemented in bridge structures, there is a future scope in application and implementation of these technologies on small scale buildings and skyscrapers.

REFERENCES

1. *Zhu, Dapeng, Xiaohua Yi, Yang Wang, Jiajie Guo, and Kok -Meng Lee. "Mobile Sensor Networks: A New Approach for Structural Health Monitoring", Structures Congress 2010.*
2. *Lim R S et.al; (2011), 'Developing a crack inspection robot for bridge maintenance', Proc. of IEEE international conference on robotics and automation, Shanghai.*
3. *Psimoulis, P., Stiros, S., (2011). Recording the response of a train passing from a short-span bridge using a Robotic Theodolite (RTS), GIM International, Vol. 25 (4), pp. 29-33.*
4. *Srividhya K., Ramya M. M. "Performance analysis of pre-processing filters for under water images", 2015 International Conference on Robotics, Automation, Control and Embedded Systems (RACE), 2015*
5. *Stiros, S. and Psimoulis, P., (2010). Identification of near-shore wave characteristics using Robotic Total Station (RTS), Journal of Surveying Engineering ASCE, Vol. 136 (4), pp. 172-179.*
6. *Mengistu, A. D., & Alemayehu, D. M. Robot For Visual Object Tracking Based On Artificial Neural Network.*
7. *Abdulla A S A et.al; (2010), 'Localization of a submersible mobile inspection platform in an oil storage tank', Proc. 7th International Symposium on Mechatronics and its Applications (ISMA), 1 – 6.*
8. *J R Chang et.al; (2007) "The Study in Using an Autonomous Robot for Pavement Inspection", 24th International Symposium on Automation and Robotics in Construction, IIT Madras.*
9. *Brunner, F. (2006). Bridge Monitoring: external and internal sensing issues, In: Ou J. P., Li H. & Duan Z. D. (Eds.) Structural Health Monitoring and Intelligent Infrastructure, 693 – 698. Balkema.*
10. *Cosser, E., Roberts, G. W, Meng, X. and Dodson, A. H. (2003), Measuring the dynamic deformation of bridges using a total station. Proc. of 11th FIG Symposium on Deformation Monitoring, 2003. Santorini, Greece.*